

AIAA-2010-8096

Effects of Spatio-Temporal Aliasing on Pilot Performance in Active Control Tasks

Peter Zaal and Barbara Sweet

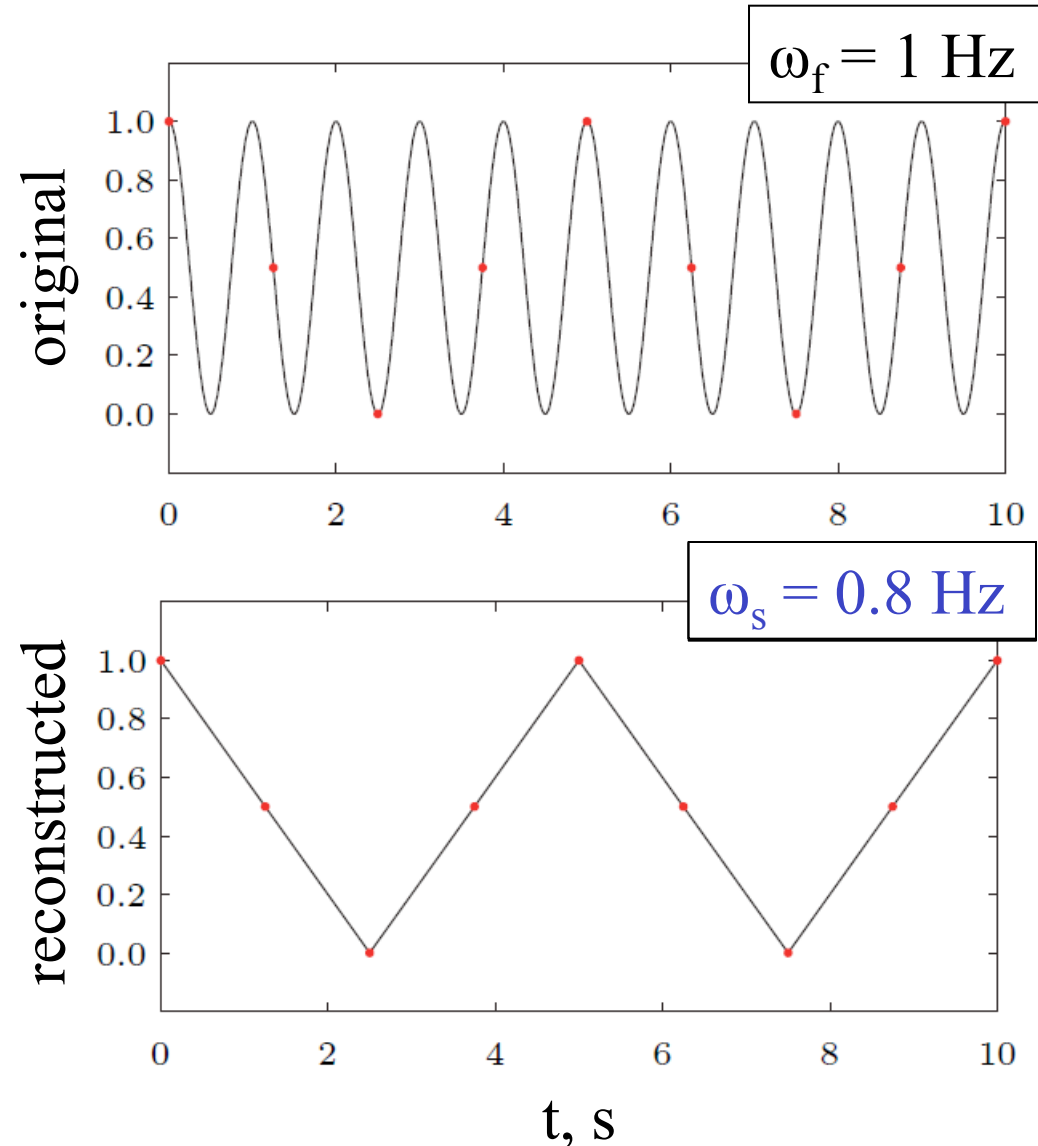
AIAA Modeling and Simulation Technologies Conference, 8-3-2010

Objective

- Spatio-temporal aliasing is present in simulator displays due to spatial and temporal image sampling.
- Experiments have been conducted that indicate the effects on visual perception.
- Objective:
Investigate the effects of spatio-temporal aliasing on pilot performance in active control tasks.

Temporal Aliasing

- $\omega_N = 0.5 \omega_s$
- Aliasing occurs if:
 $\omega_N < \omega_f$
- The reconstruction appears to have a different fundamental frequency.
- Magnitude is only preserved if $\omega_N \gg \omega_f$

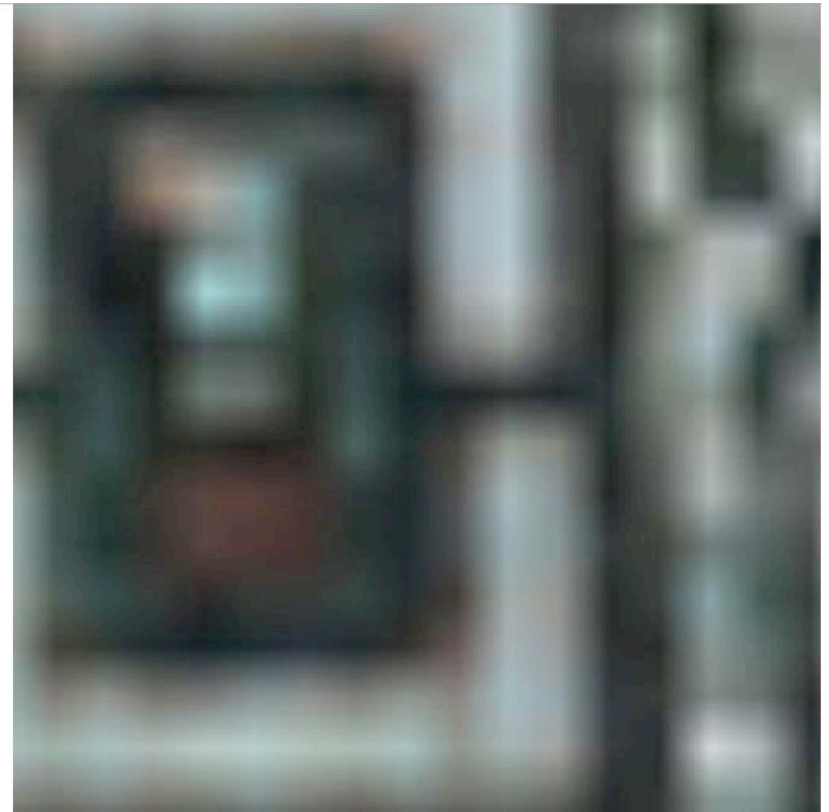


Spatial Aliasing

256x256 px



16x16 px

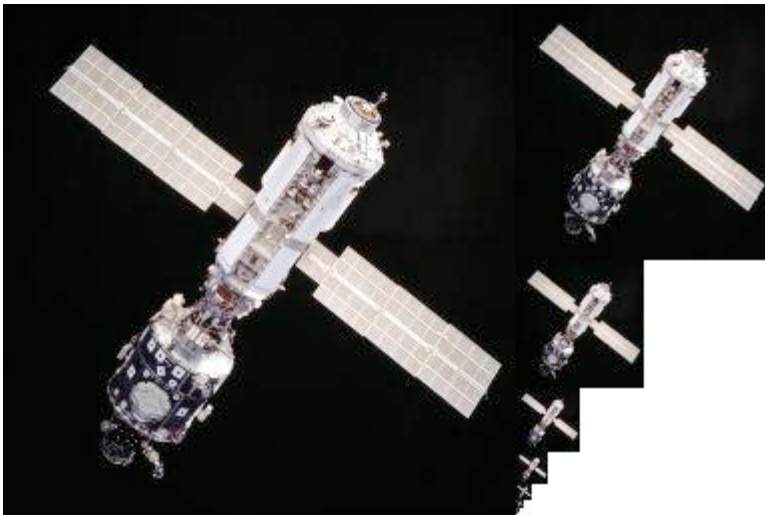


Lindholm et al. 2003

Spatial Aliasing

Anti-aliasing techniques exist to reduce spatial aliasing:

- Filtering
- Mipmapping
- Ripmapping

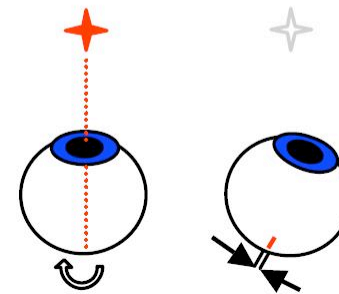
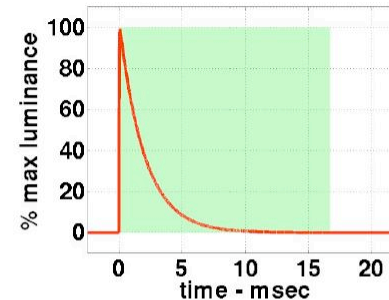


Sweet et al. 2008

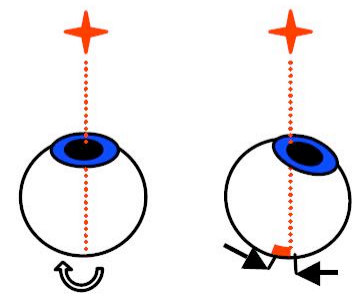
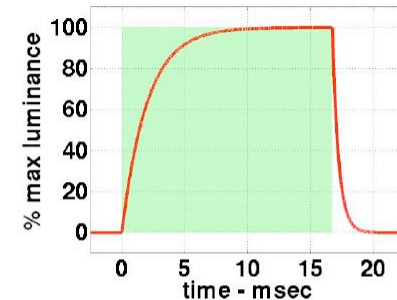
Image Motion Artifacts

- Motion induced blur:
 - Related to the response and hold time of LCD displays.

CRT



LCD



- Spatio-temporal aliasing:
 - Related to the temporal sampling of an image in motion.

Sweet et al. 2007

Spatio-Temporal Aliasing

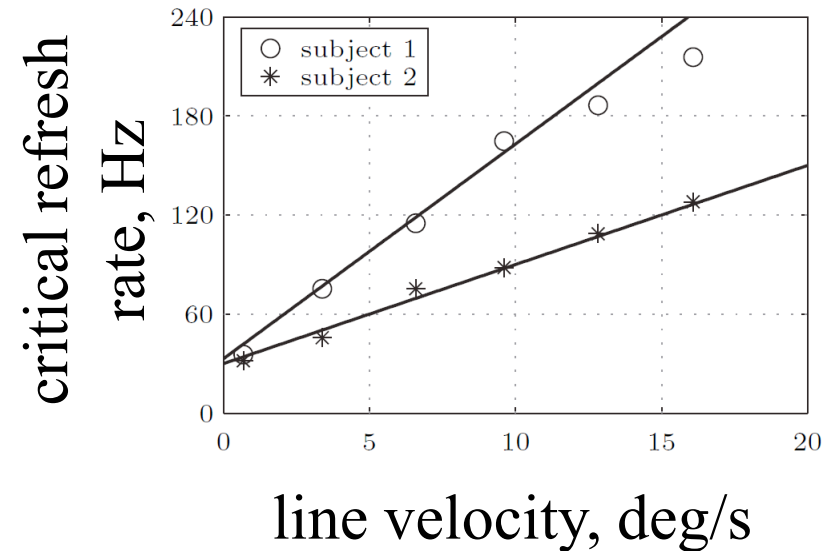


Spatio-Temporal Aliasing

Previous research:

- Mostly passive task experiments
 - Watson et al.
 - Kuroki et al.
 - Winterbottom et al.
- Active task experiment
 - Dearing et al.

Watson et al.



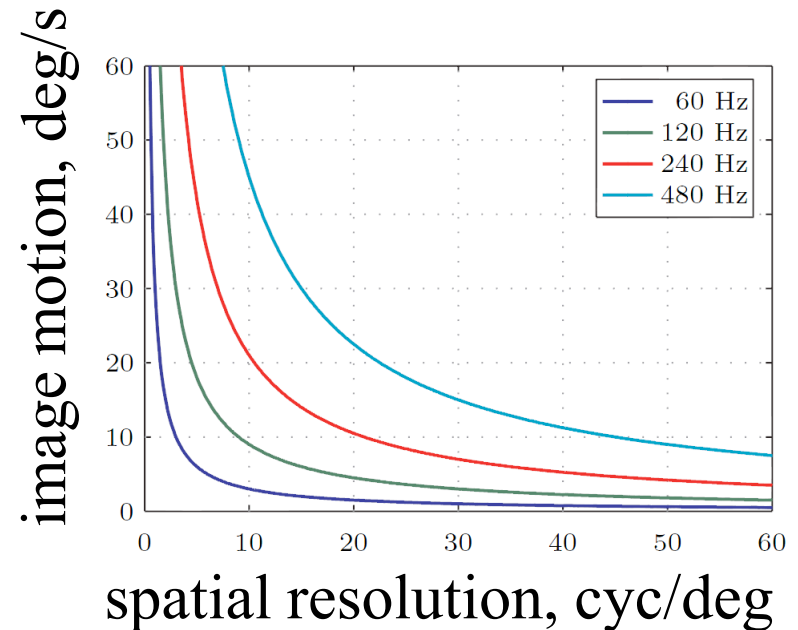
Spatio-Temporal Aliasing

Spatio-temporal aliasing is dependent on:

- Maximum spatial frequency of image.
- Image motion speed.
- Display refresh rate.

Critical sampling frequency
is a linear function of image
motion:

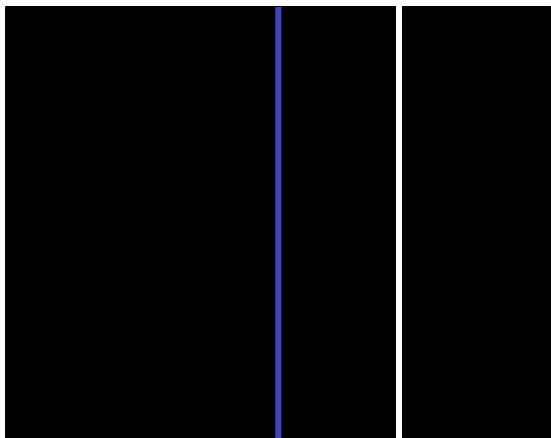
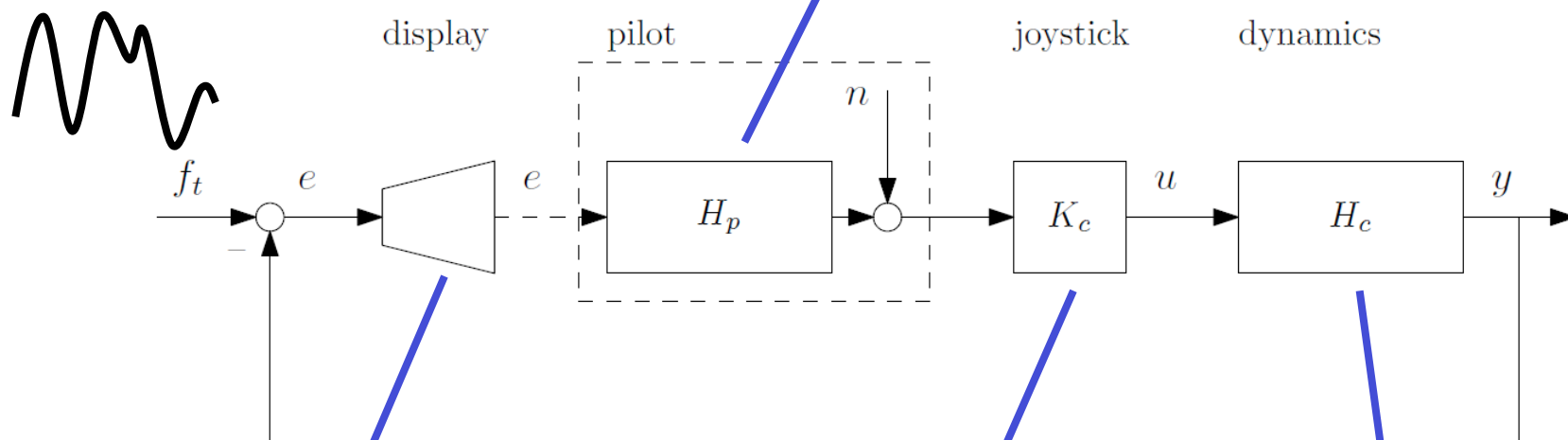
$$\omega_{cs} = \omega_l + ru_b$$



Experiment Setup

Control task:

$$K_v(1 + T_{lead}s)e^{-\tau_v s} \frac{\omega_{nm}^2}{\omega_{nm}^2 + 2\zeta_{nm}\omega_{nm}s + s^2}$$



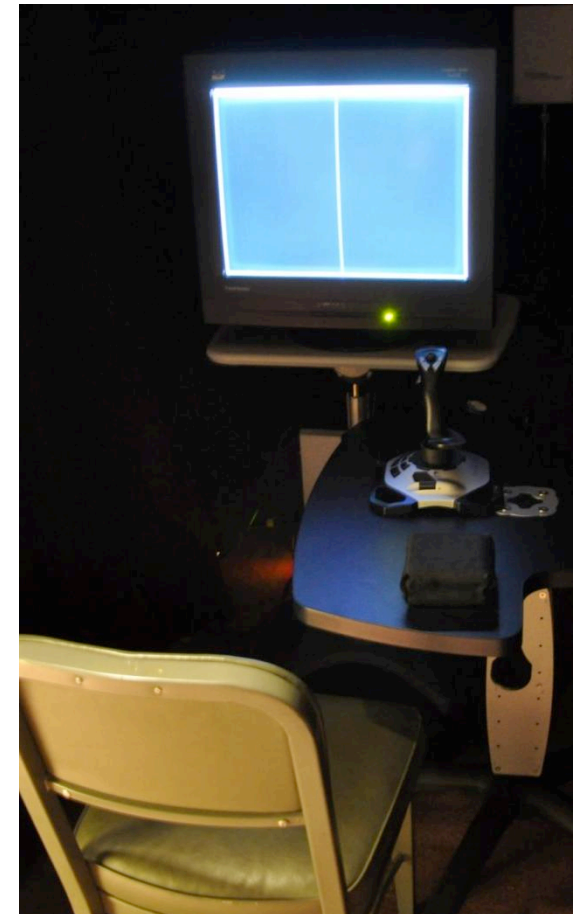
$$K_c = 3$$

$$H_c(s) = \frac{600}{s(s + 0.2)}$$

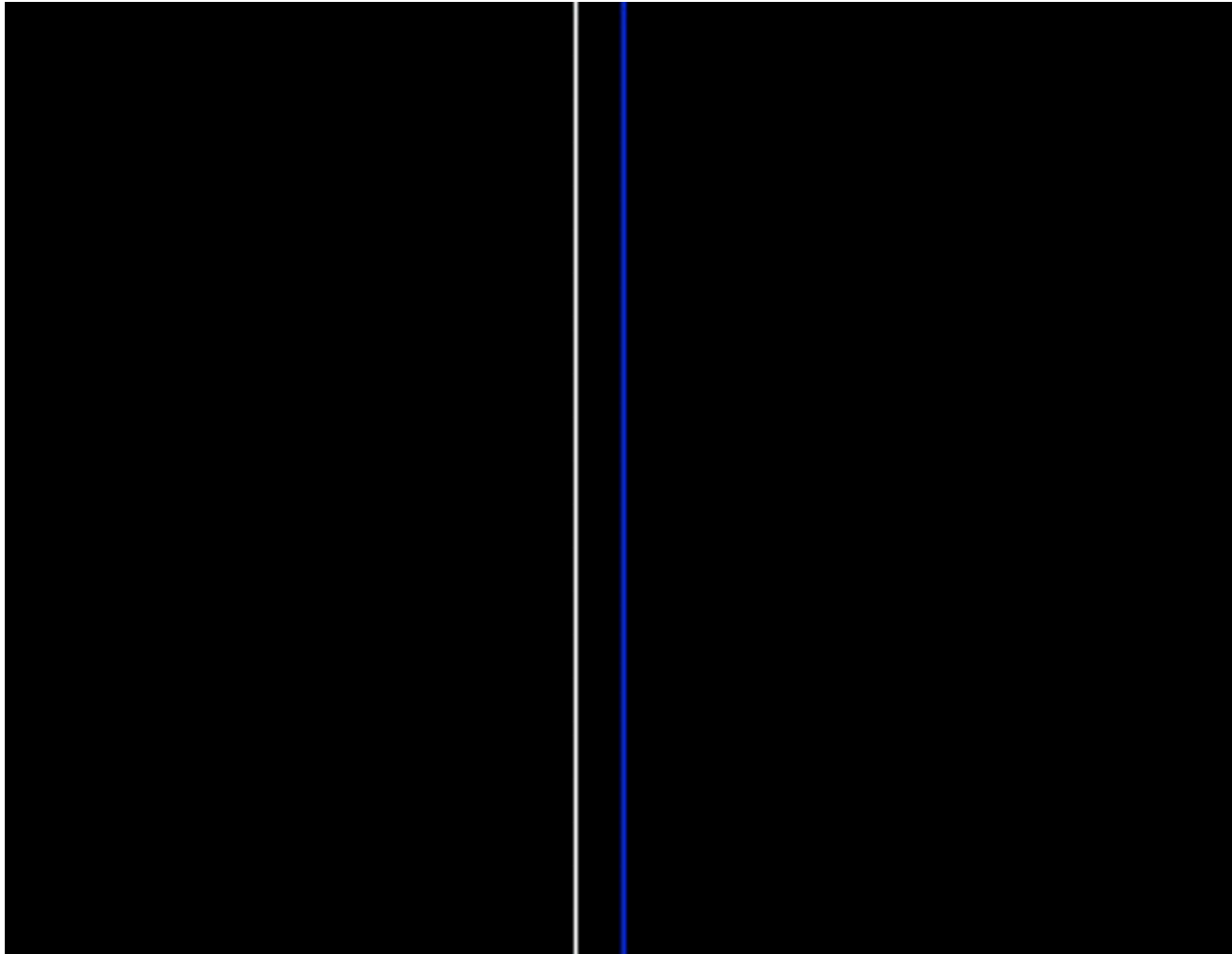
Experiment Setup

Spatio-temporal aliasing:

- Refresh rate: 60, 75, 90, 105, 120 Hz
- Constant spatial frequency content
- Constant velocity profile
- Latin-square design
- Software updates at 120 Hz
- 10 general aviation pilots



Experiment Setup

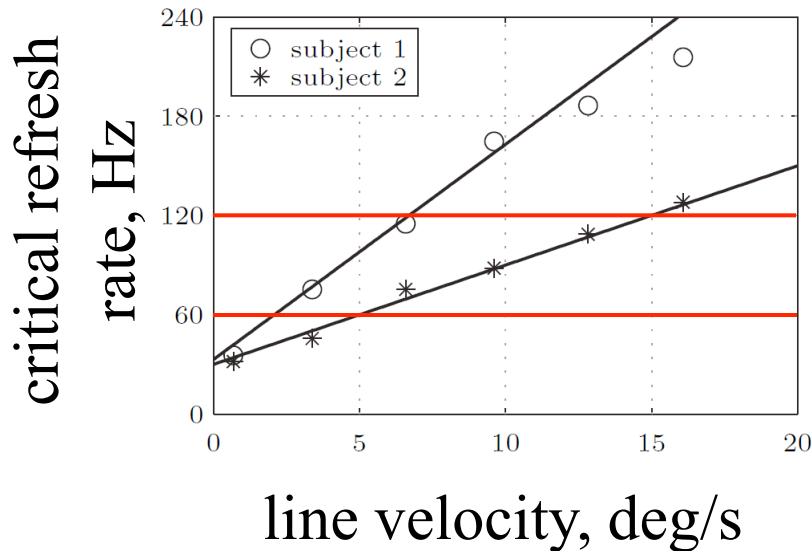


Results

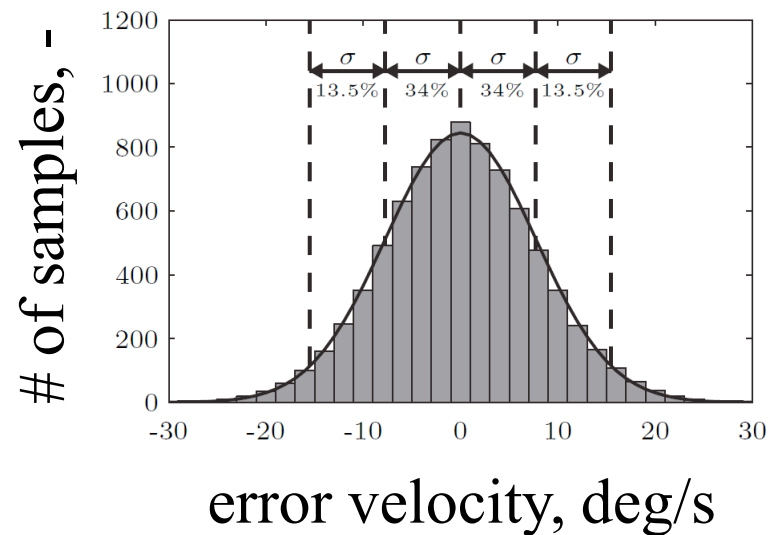
Spatio-temporal aliasing was present in all conditions:

- Confirmed by pilots.
- Velocity of stimulus sufficiently high.

Watson et al.



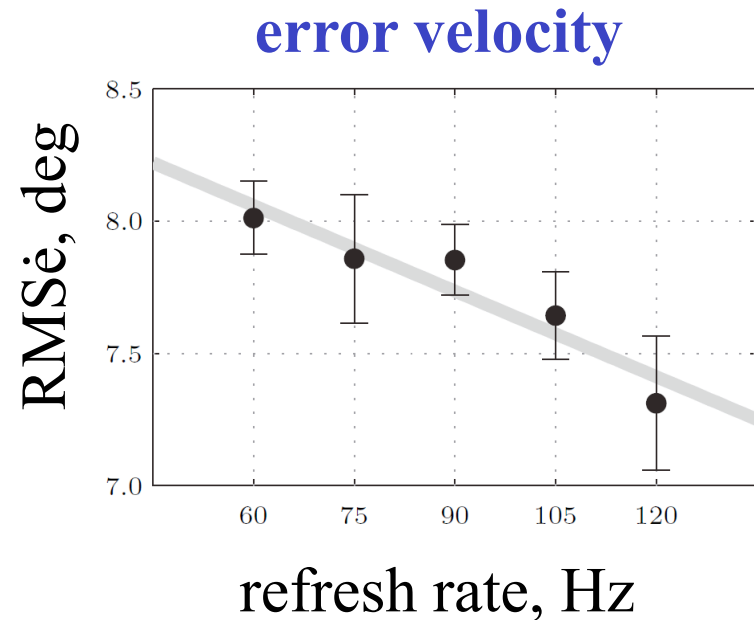
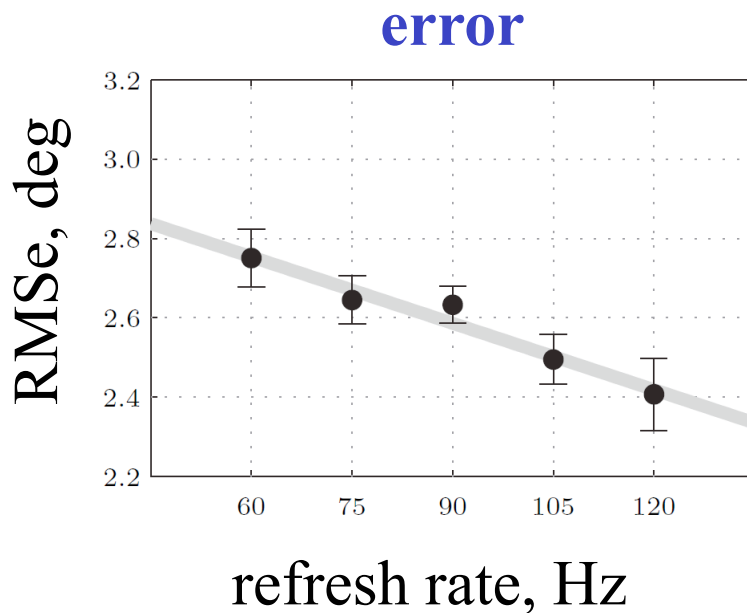
current experiment



Results

Performance:

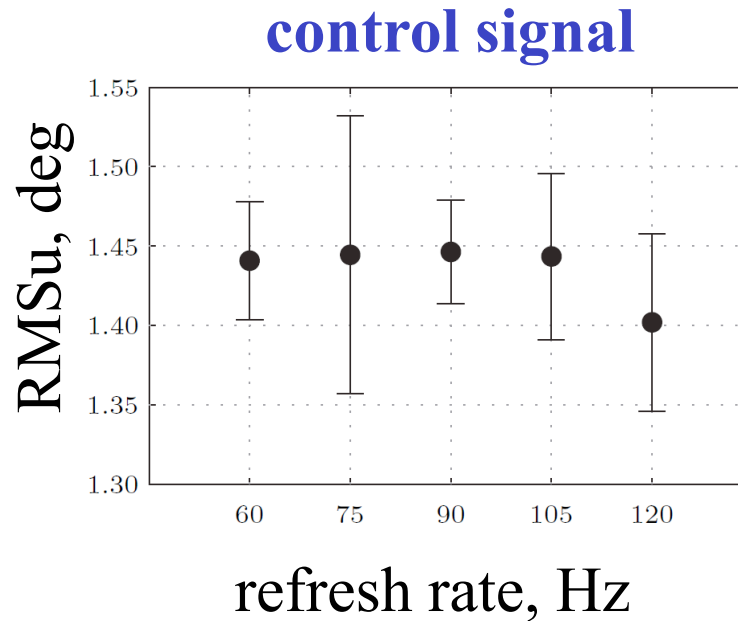
- Decrease in RMS of the error and error velocity.
- Significant trends are linear.



Results

Control effort:

- No significant effect for the RMS of the control signal.

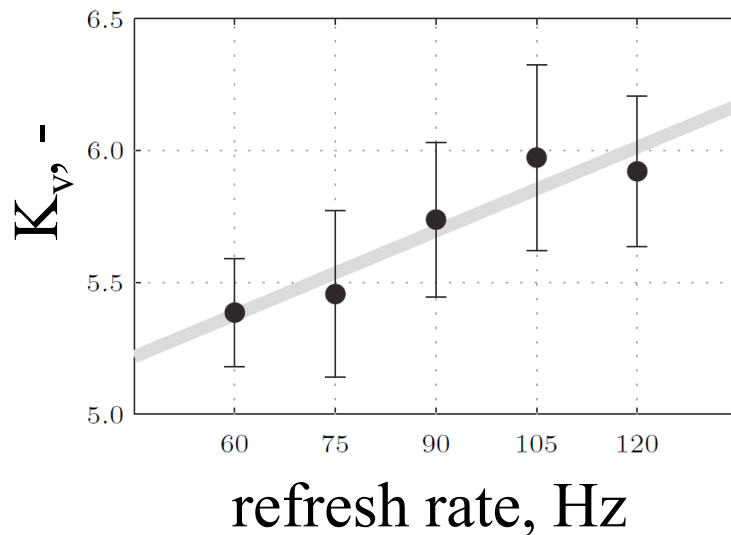


Results

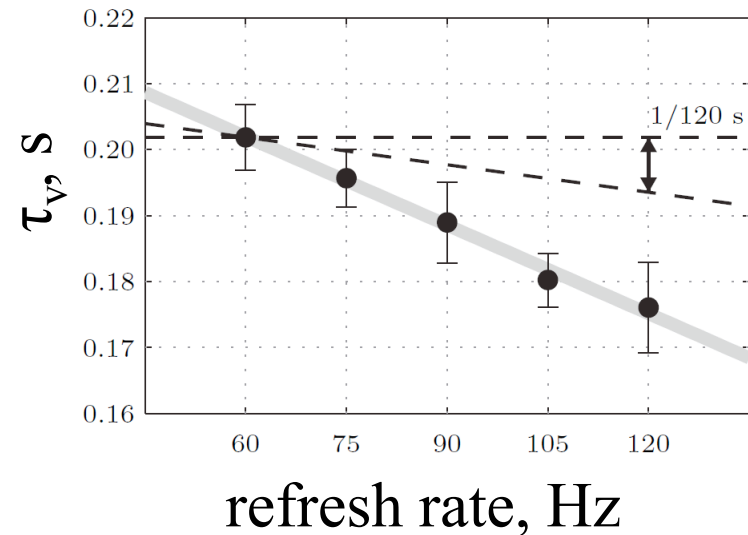
Pilot model parameters:

- Increase in visual gain, decrease in visual time delay.
- Linear trends.

visual gain



visual delay

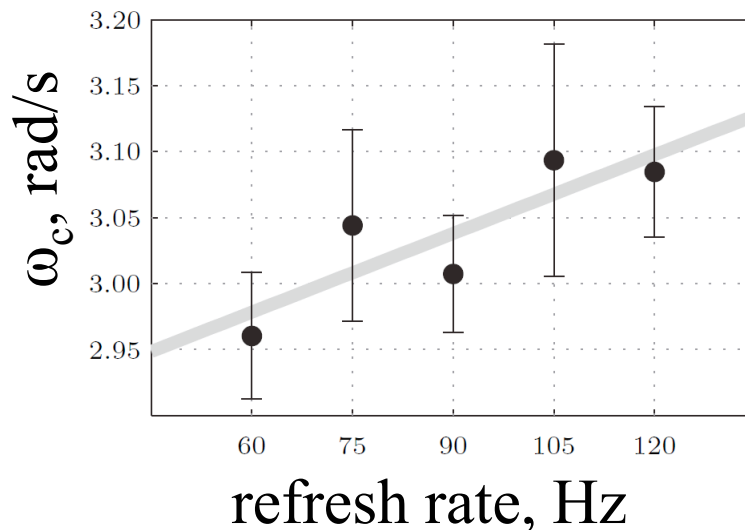


Results

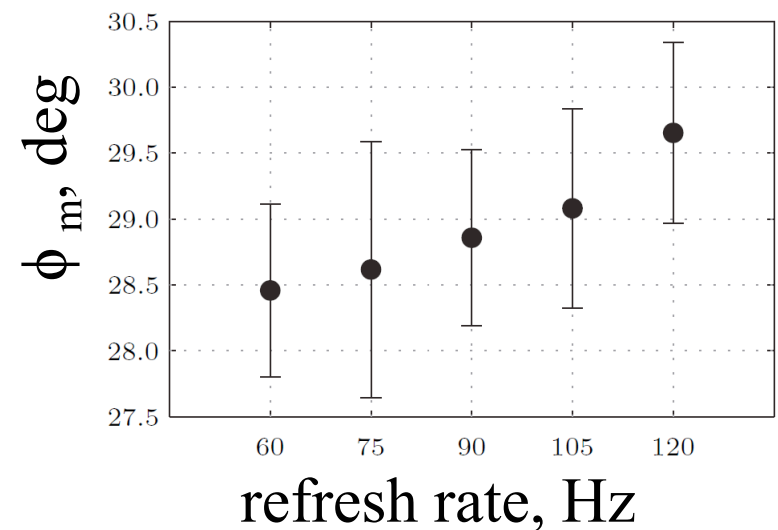
Open-loop characteristics:

- Significant linear increase in crossover frequency.
- Nonsignificant increase in phase margin.

crossover frequency



phase margin



Conclusions

Spatio-temporal aliasing affects pilot performance and control behavior.

For increasing refresh rates:

- Significant change in control behavior:
 - Increase in visual gain and neuromuscular frequency.
 - Decrease in visual time delay.
- Increase in tracking performance:
 - Decrease in RMSe.
 - Increase in crossover frequency.

Future Research

- More realistic tasks (larger FOV).
- Higher refresh rates ($120 <$).
- Eye movements.

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